May averages for Washington. Measurements at Madison give a mean of 54 per cent, with a maximum of 64 per cent on the 5th.

Table 3 shows a deficiency in the total radiation for the month of 7 per cent at Washington and an excess of 10 per cent at Madison.

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Dates.	A. M.	P. M.	Dates.	A. M.	P. M.	Dates.	A. M.	P. M.	Dates.	A. M.	P. M.
1917.	*mm.*	*mm.*	1917.	*mm.*	*mm.*	1917.	*mm.*	*mm.*	1917.	*mm.*	*mm.*
May 1	10.21	4.75	May 2	4.95	3.99	May 5	4.57	7.29	May 1	3.15	1.07
2	4.17	3.99	5	3.15	4.17	6	4.17	4.17	2	2.62	2.16
9	6.50	3.99	7	4.37	3.99	7	4.37	4.17	16	4.57	1.88
10	4.57	4.37	9	4.75	4.17	11	6.27	4.75	17	3.00	1.68
11	6.27	3.99	10	3.99	4.17	14	5.16	4.17	26	3.45	3.99
15	5.36	3.00	11	4.37	4.95	15	5.16	4.75	28	3.63	1.60
16	7.29	5.66	12	4.57	5.36	16	5.56	7.87	31	3.15	3.45
18	9.14	9.14	14	5.36	7.04	17	10.97	7.29			
23	13.13	4.17	23	2.87	4.57	22	6.02	4.17			
24	5.56	3.81	24	3.63	5.79	28	7.04	8.81			
25	5.16	4.95	25	6.02	6.76	31	8.48	9.14			
26	5.56	9.14	28	6.02	5.79						
30	7.87	9.14	29	7.57	9.83						

TABLE 3.—*Daily totals and departures of solar and sky radiation during May, 1917.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
1917.	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*
May 1	444	372		−23	−82		−23	−82	
2	630	563		161	107		138	25	
3	547	528		75	71		213	96	
4	90	314		−385	−144		−172	−48	
5	52	389		−426	−70		−598	−118	
6	394	367		−86	−93		−684	−211	
7	328	696		−154	235		−838	24	
8	190	501		−295	40		−1,133	64	
9	429	684		−58	222		−1,191	286	
10	538	651		49	188		−1,142	474	
11	563	702		72	238		−1,070	712	
12	488	614		−5	150		−1,075	862	
13	574	697		79	232		−996	1,094	
14	623	649		126	183		−870	1,277	
15	690	605		191	139		−679	1,416	
16	479	662		−20	195		−699	1,611	
17	408	593		−91	125		−790	1,736	
18	589	577		90	108		−700	1,844	
19	606	610		108	140		−592	1,984	
20	502	537		4	67		−588	2,051	
Decade departure							554	1,577	
21	516	55		19	−416		−569	1,635	
22	406	200		−90	−272		−659	1,363	
23	546	712		50	239		−609	1,602	
24	526	713		30	239		−579	1,841	
25	427	683		−68	208		−647	2,049	
26	596	136		102	−340		−545	1,709	
27	516	540		22	62		−523	1,771	
28	156	692		−337	213		−860	1,984	
29	236	594		−256	113		−1,116	2,097	
30	680	123		189	−359		−927	1,738	
31	376	243		−114	−241		−1,041	1,497	
Decade departure							−453	−554	
Excess or deficiency since first of year. Gr.-cal.							−2,541	+2,172	
Excess or deficiency since first of year. Per cent.							−5.0	+4.4	

NOTE.

There is evidence that the records of total solar and sky radiation at Lincoln, Nebr., and of the intensity of direct solar radiation at Santa Fe, N. Mex., are inaccurate. Publication of these data is therefore deferred until the instrumental constants have been redetermined.

551.591

CITY SMOKE AND DAYLIGHT ILLUMINATION INTENSITIES.

By HERBERT H. KIMBALL, Professor of Meteorology, and ALFRED H. THIESSEN, Meteorologist.

[Weather Bureau, Washington, May 24, 1917.]

One of us [1] has already called attention to the considerable diminution in daylight illumination, especially in winter, in cities where soft coal is burned, due to the presence of smoke in the atmosphere. At Salt Lake City, Utah, this effect is specially marked in the early morning hours, and when the wind is light it sometimes persists for a considerable time. In order to determine the extent of the diminution, photometric measurements were made by Mr. Thiessen with the Sharp-Millar photometer described in the MONTHLY WEATHER REVIEW for December, 1914, 42:648–653, the instrument having been lent him by the central office of the Weather Bureau for this purpose.

In this study a comparison is made between the readings obtained at Salt Lake City on four different days, as follows: February 15 and 16, 1916, which were cloudless, but with much smoke in the atmosphere, and September 1 and 28, 1916, on which neither cloud nor smoke was observed. The readings are given in Table 1.

It will be noticed that each series of readings usually includes three independent photometric determinations. The mean of each series has been reduced to foot-candles of illumination by a factor derived from the constants given in the REVIEW for December, 1914, 42:650. The milk glass screen and blue glass VIA, there described, have always been used. Column 4 of Table 1, headed "Scr.," indicates when screen L or D has also been used.

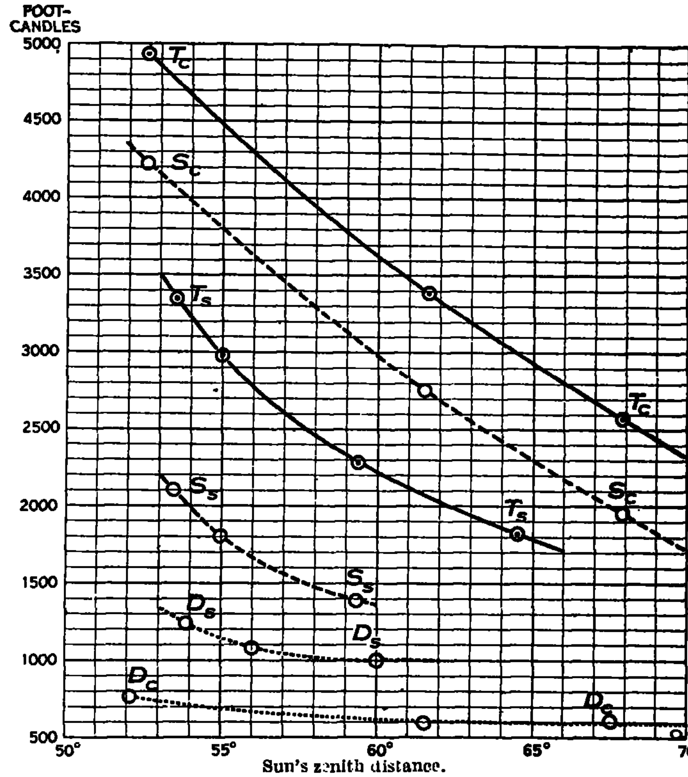

FIG. 1.—Comparison of illumination intensities at Salt Lake City, Utah, with clear and with smoky sky:

—— T_c = Total illumination, with clear sky; T_s = Total illumination, with smoky sky;
– – – S_c = Direct solar illumination, with clear sky; S_s = Direct solar illumination, with smoky sky;
······ D_c = Diffuse sky illumination, with clear sky; D_s = Diffuse sky illumination, with smoky sky.

[1] *Kimball, Herbert H.* The meteorological aspect of the smoke problem. Smoke Investigation Bulletin No. 5, Mellon Institute of Industrial Research and School of Specific Industries, University of Pittsburgh, 1913; also MONTHLY WEATHER REVIEW, January, 1914, 42:29–35.

TABLE 1.—*Photometric determinations of daylight intensity on a horizontal surface at Salt Lake City, Utah, latitude, 40° 46′; longitude, 111° 54′.*

Date.	(1) Sun's— Hour angle.	(2) Sun's— Zenith distance.	(3) Exp.	(4) Scr.	(5) Photometer readings. 1	(6) Photometer readings. 2	(7) Photometer readings. 3	(8) Photometer readings. Means.	(9) I	(10) IR^2	(11) I_sR^2
1916.	H. m.	°							Ft.-candles.	Ft.-candles.	Ft.-candles.
Feb. 15	A. M.										
	2 35	64.5	T.	L.	8.02	7.95	8.00	7.99	1,867	1,822	....
	2 16	62.2	T.	L.	11.10	11.10	12.00	11.40	2,664	2,600	1,650
	2 12	61.8	S.	L.	4.30	4.30	4.00	4.20	982	958	....
	1 55	59.9	T.	L.	12.00	12.00	12.50	12.17	2,844	2,776	1,740
	1 52	59.6	S.	L.	4.41	4.32	4.50	4.41	1,061	1,036	....
	1 42	58.6	T.	L.	9.20	9.20	10.00	9.47	2,231	2,177	1,150
	1 41	58.5	S.	L.	4.50	4.45	4.50	4.48	1,047	1,022	....
	1 17	56.6	T.	L.	8.70	8.90	8.70	8.77	2,050	2,001	1,020
	1 12	56.2	S.	L.	4.30	4.11	4.45	4.29	1,003	979	....
	0 57	55.3	T.	L.	12.00	12.00	11.70	11.90	2,781	2,714	1,540
	0 57	55.3	S.	L.	5.10	5.18	5.10	5.13	1,199	1,170	....
Feb. 16	A. M.										
	0 52	54.7	T.	L.	14.50	14.75	13.90	14.38	3,365	3,284	1,980
	0 47	54.4	S.	L.	6.20	5.60	5.40	5.73	1,339	1,307	....
	0 29	53.8	T.	L.	12.50	12.50	13.00	12.67	2,968	2,897	1,710
	0 25	53.7	S.	L.	5.00	5.20	5.40	5.20	1,215	1,186	....
	0 07	53.4	T.	L.	15.00	15.00	15.60	15.20	3,552	3,467	1,920
	0 04	53.4	S.	L.	6.70	7.00	6.70	6.80	1,589	1,551	....
	P. M.										
	0 08	53.4	T.	L.	15.00	15.00	......	15.00	3,506	3,422	2,120
	0 10	53.4	S.	L.	5.80	5.50	5.80	5.70	1,332	1,300	....
	0 19	53.6	T.	L.	15.00	15.50	17.00	15.83	3,692	3,603	2,070
	0 22	53.6	S.	L.	4.80	4.40	4.45	4.55	1,063	1,037	....
	0 38	54.1	T.	L.	14.00	14.10	14.10	14.07	3,295	3,216	2,040
	0 40	54.2	S.	L.	5.20	5.30	5.00	5.17	1,208	1,179	....
	0 53	54.8	T.	L.	12.50	13.00	12.50	12.67	2,968	2,897	1,780
	0 55	54.8	S.	L.	4.70	4.80	5.00	4.83	1,129	1,112	....
	1 13	56.0	T.	L.	11.30	11.80	13.00	12.03	2,811	2,744	1,670
	1 18	56.4	S.	L.	4.80	4.50	4.80	4.70	1,098	1,072	....
Sept. 1	A. M.										
	3 03	52.0	T.	D.	7.9	7.8	7.9	7.87	6,192	6,303	5,290
	2 53	50.3	S.	L.	4.2	4.4	4.2	4.27	998	1,016	....
	2 28	46.2	S.	L.	4.0	3.9	3.9	3.93	918	935	....
	2 23	45.4	T.	D.	7.7	7.8	7.7	7.73	6,082	6,192	5,260
	1 33	38.6	T.	D.	9.6	9.0	9.6	9.40	7,396	7,529	6,570
	1 28	38.0	S.	L.	4.0	4.1	4.0	4.03	942	959	....
	0 43	33.9	S.	L.	4.2	......	......	4.20	982	1,000	....
	0 40	33.8	T.	D.	9.8	9.5	9.8	9.70	7,634	7,772	6,770
	P. M.										
	1 07	35.9	T.	D.	9.8	9.7	9.5	9.67	7,608	7,745	6,740
	1 12	36.3	S.	L.	4.2	4.4	4.0	4.20	982	1,000	....
	2 17	44.5	S.	L.	3.5	3.4	......	3.45	806	821	....
	2 17	44.5	T.	D.	8.2	8.2	8.5	8.30	6,530	6,648	5,830
	3 17	54.4	T.	D.	5.7	6.0	5.8	5.83	4,587	4,670	3,950
	3 19	54.7	S.	L.	2.9	3.2	3.0	3.03	708	721	....
	4 07	63.6	S.	L.	2.5	2.5	......	2.50	584	595	....
	4 09	63.8	T.	L.	16.9	16.5	17.1	16.83	3,826	3,895	3,300
Sept. 28	A. M.										
	4 13	71.5	T.	D.	3.2	3.3	3.3	3.27	2,573	2,581	2,090
	4 03	69.8	S.	......	15.1	15.15	15.2	15.15	489	490	....
	3 49	67.3	T.	L.	11.0	11.0	12.0	11.33	2,648	2,656	2,100
	3 46	66.8	S.	L.	2.5	2.3	2.3	2.37	554	556	....
	3 25	63.3	T.	L.	14.0	14.5	14.0	14.17	3,312	3,322	2,860
	3 15	61.6	S.	......	14.0	14.5	......	14.25	460	461	....
	3 03	59.7	T.	L.	16.0	16.0	17.0	16.33	3,816	3,827	3,320
	2 57	58.8	S.	......	15.5	15.5	16.0	15.67	506	508	....
	2 31	54.9	T.	L.	19.0	19.5	19.0	19.17	4,480	4,493	3,890
	2 28	54.5	S.	......	19.0	19.0	17.5	18.50	597	599	....
	2 03	51.2	T.	D.	6.2	6.2	6.2	6.20	4,878	4,893	4,270
	1 54	50.1	S.	L.	2.5	2.7	2.8	2.67	624	626	....
	1 16	46.2	S.	L.	2.8	2.5	2.4	2.57	601	603	....
	1 11	45.8	T.	D.	6.9	6.5	6.8	6.73	5,303	5,319	4,720
	0 53	44.5	T.	D.	7.2	7.25	7.4	7.28	5,728	5,745	5,160
	0 49	44.3	S.	L.	2.5	2.55	2.6	2.55	596	598	....
	0 18	43.9	S.	L.	3.2	3.3	3.2	3.23	755	757	....
	0 15	43.0	T.	D.	7.6	7.8	7.8	7.73	6,082	6,100	5,340
	P. M.										
	0 15	43.0	T.	D.	8.5	8.6	8.8	8.63	6,790	6,810	6,040
	0 18	43.9	S.	L.	3.55	3.0	3.3	3.28	766	768	....
	1 02	45.1	S.	L.	3.4	3.25	3.75	3.47	811	813	....
	1 06	45.4	T.	D.	7.0	7.1	6.8	6.97	5,484	5,500	4,690
	1 44	49.0	T.	D.	6.1	6.2	6.2	6.17	4,854	4,869	4,110
	1 48	49.4	S.	L.	3.1	3.15	3.5	3.25	760	762	....
	2 23	53.8	S.	L.	3.6	3.4	3.65	3.55	830	832	....
	2 24	54.0	T.	L.	18.0	18.2	17.9	18.03	4,214	4,227	3,400
	2 56	58.6	T.	L.	12.7	12.7	12.7	12.70	2,968	2,977	2,170
	2 58	58.9	T.	L.	13.8	14.0	13.8	13.87	3,248	3,258	2,450
	3 17	62.0	S.	L.	3.5	3.4	3.4	3.43	795	797	....
	3 19	62.3	T.	L.	11.2	12.0	11.8	11.67	2,734	2,742	1,950
	3 35	64.9	T.	L.	10.0	10.0	10.2	10.07	2,453	2,460	1,660
	3 40	65.8	S.	L.	3.4	3.5	3.3	3.40	795	797	....

Column 3 of Table 1, headed "Exp.," indicates by *T* and *S*, respectively, whether the photometer was exposed to the total hemispherical vault of the sky, including that part occupied by the sun, or to the sky alone. In the latter case a screen was interposed between the instrument and the sun. In column 10, the illumination intensity, *I*, has been reduced to intensity for mean solar distance of the earth by multiplying it by the square of the earth's radius vector, R^2. The illumination intensity, I_s, due to direct solar radiation alone, and likewise reduced to mean solar distance, is given in the last column of Table 1. It has been obtained by subtracting the diffuse sky illumination from the total illumination.

The data of columns 10 and 11 for the two clear days, and likewise for the two smoky days, have been grouped by the zenith distance of the sun at the time of the measurements, and the means of each group are plotted in figure 1.

From the curves thus constructed the comparisons given in Table 2 between the total, the direct solar, and the diffuse sky illuminations, on clear and on smoky days, have been obtained. From these comparisons it appears that on a smoky day the total daylight illumination is about two-thirds and the direct solar illumination is about one-half what it is on a clear day, while the diffuse sky illumination is about one and two-thirds times the illumination from a clear sky. As a result of the above the diminution in daylight illumination will be relatively less in rooms on the shaded sides of buildings than in rooms on the sunny side.

The diminution in the total, and in the direct solar, illumination is generally intensified with increase in the sun's zenith distance, while at the same time the increase in the intensity of diffuse skylight becomes less marked.

The smoke cloud at Salt Lake City rises to a height of about 400 feet above the level of the business streets. Often the sky is clear at the time of the 6 a. m. (8 a. m. 75th meridian time) observation, but becomes smoky by 7 a. m., and when the wind is light it remains smoky all day long. Such days may be called "dark days." February 16, 1916, was a dark day, and February 15 was dark until about noon.

From November 1 to March 31 the number of days with light smoke averages 82, and with dense smoke 25, making in all about 107 smoky days out of a total of 151 days. When the smoke is dense artificial light must be used quite late in the morning and early in the evening, and sometimes throughout the day. This means a very considerable expense to the private family as well as to the manufacturer and merchant and is directly chargeable to the smoke.

TABLE 2.—*Comparison of illumination intensities on clear and smoky days at Salt Lake City, Utah.*

[Unit: Foot-candle.]

Sun's zenith distance.	Total illumination. Clear sky.	Total illumination. Smoky sky.	Total illumination. *Ratio, smoky to clear.*	Solar illumination. Clear sky.	Solar illumination. Smoky sky.	Solar illumination. *Ratio, smoky to clear.*	Sky illumination. Clear sky.	Sky illumination. Smoky sky.	Sky illumination. *Ratio, smoky to clear.*
°									
53.5	4,740	3,360	*0.71*	4,050	2,100	*0.52*	730	1,270	*1.74*
55.0	4,460	2,980	*0.67*	3,780	1,800	*0.48*	700	1,140	*1.63*
59.0	3,770	2,320	*0.62*	3,110	1,400	*0.45*	640	1,000	*1.56*
61.5	3,400	2,070	*0.61*	....	....	....	....	....	....
64.5	2,990	1,820	*0.61*	....	....	....	....	....	....
Means	....	....	**0.64**	....	....	**0.48**	....	....	**1.64**

The total and direct solar illumination intensities of September 1 and 28 average a little higher than those for Mount Weather, Va., at the same season of the year, as published in the REVIEW for December, 1914, above referred to. The diffuse sky illumination, however, is markedly less.

It is of interest to note that the results of this investigation show about the same percentage of diminution in daylight illumination under the city smoke cloud as was given by a comparison between the decomposition of oxalic acid at Pittsburgh, Pa., and at Sedgwick, Pa., the latter a suburb of Pittsburgh.[3]

551.594

ON HORIZONTAL HALOS.

By Y. TSUJI.

[*Reprinted from* Journal of the Royal Meteorological Society of Japan, May, 1917, 36: 53.]

Horizontal halos are produced by the refraction of the sun's rays at the surface of frost crystals of tabular form deposited on the surface of snow or ground, or [at the surface] of freshly fallen snow crystals. The author of this article describes 50 cases of ground halos observed at Ueda in Nagano prefecture, central Japan. In a general consideration of these optical phenomena he has deduced the equation for them in the following way:

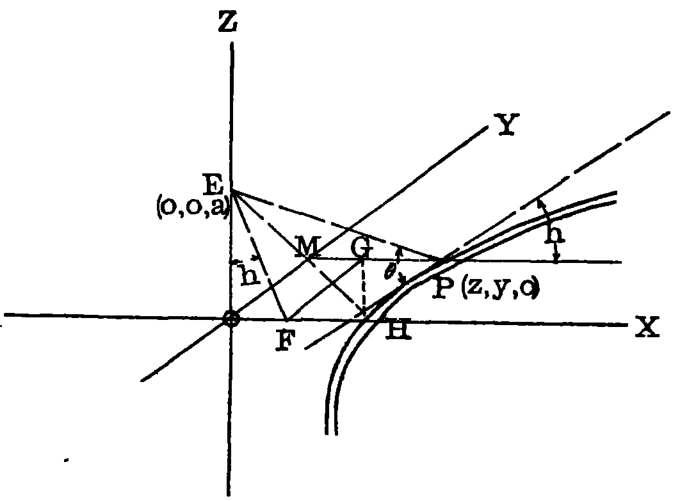

FIG. 1.—Construction illustrating Tsuji's demonstration on ground halos.

In figure 1 let θ be the angle of deviation of the solar rays through an ice prism. Taking the vertical through the observer as Z-axis and X and Y axes in the plane of the halo, we get as the equation of the halo

$$(a^2+x^2+y^2)^{\frac{1}{2}} \cos \theta = (x - a \tan h) \cos h,$$

where a is the height of the observer's eye, and h the sun's altitude.

Transforming the origin of the coordinates to the center of symmetry the equation becomes,

$$\frac{\xi^2}{\frac{\cos^2\theta \sin^2\theta}{(\cos^2 h - \cos^2\theta)^2}} - \frac{\eta^2}{a^2 \frac{\sin^2\theta}{\cos^2 h - \cos^2\theta}} = 1.$$

The angle of deviation of the rays deduced from the observation of the horizontal halos is considerably greater than 22° for the inner halo, and than 46° for the exterior halo. This shows that the explanation of the halos afforded by the geometrical method was unsatisfactory and must be founded on the principles of physical optics.—*T. Okada.*

[3] *See* MONTHLY WEATHER REVIEW, January, 1914, 42:32.

SOLAR HALO AT VICKSBURG, MISS., APRIL 24, 1917.[1]

551.594 (762)

By WILLIAM E. BARRON, Meteorologist.

[Weather Bureau Office, Vicksburg, Miss.]

Unusual halo phenomena were observed at Vicksburg, Miss., on April 24, 1917. Attention was first directed to the phenomena at 11:15 a. m., 90th meridian time, and they continued visible until 12:15 p. m. In the first place there was an ordinary halo usually mentioned as of 22° radius. The circle was well defined and the colors were brilliant. But the most striking phenomenon was a circumhorizontal arc, such as is described in the MONTHLY WEATHER REVIEW, July, 1914, page 440. The colors of this arc were most brilliant, showing all of the spectral colors over a belt estimated at 3° in width, the red being nearest the sun, and the violet nearest the horizon. At times the band was broken owing to the shifting character of the clouds. Throughout the period there were six to seven tenths of cirrus clouds, those nearer the sun appearing to be of the more matted cirro-stratus type. During most of the appearance the arc was 40° to 50° in length, and at 11:35 a. m. extended from az. 523° to az. 43°. At about 11:40 a. m. a second complete circle was discovered, white in color and well defined, with its circumference passing through the sun, and its center north of the sun, probably in the circumference of the first circle.

It was some time before instruments could be gotten out with which to measure the angles and by that time the horizontal arc was becoming shorter, and there was some difficulty in using a transit on account of the lenses. The elevation of the red edge of the arc was found to be 25°. The elevation of the inside edge of the colored circle was found to be 50° 30′. These angles were measured at 11:55 a. m. and 12 noon, respectively. The angular elevation of the sun was not obtained at the time, but was obtained at the same time on the next day by computation from the shadows.

	°	′
Elevation of sun at 11:55 a. m., 25th	70	39
Upper edge of arc at 11:55 a. m., 24th	25	00
Angular distance of arc	45	39
Elevation of sun at 12 noon, 25th	70	46
Inner edge of circle, at 12 noon, 24th	50	30
Radius of circle	20	16

No measurements of the white circle were made on account of its height.

Parhelia with prismatic colors were observed, one above and one to the north of the sun at 6:17 p. m. The angular distance was not measured, but was thought to be about 22°. At the same time there was a vertical light pillar, about the apparent width of the sun, and extending upward from it 8° or 10°.

HALO PHENOMENA APRIL 8, 1917, AT YORK, N. Y.[1]

Mr. Milroy N. Stewart, of York, N. Y. (lat. N. 42° 52′ 30″, long., 77° 53′) contributes the following notes of halo phenomena observed April 8, 1917:

At 10:55 a. m. I noticed the very bright upper and lower arcs of a 22° halo. This caused me to look for the circumscribed halo formed by the tangent arcs, and almost immediately the arc on the western side appeared and in a very few minutes the eastern limb was apparent. At

[1] Published with approval of Division of Aerological Investigations.